APPARATUS AND METHOD FOR ENHANCING THE UNIFORM ETCHING CAPABILITY OF AN ION BEAM GRID

[0001]This Divisional Application claims the priority of Parent Application Serial No. 10/252,963 (Attorney Docket No. SJO920000053US1), filed on September 13, 2000, and entitled "Apparatus and Method for Enhancing the Uniform Etching Capability of an Ion Beam Grid".

BACKGROUND OF THE INVENTION

1. Technical Field

[0002]The present invention relates in general to an improved magnetic head slider fabrication process, and in particular to a method and apparatus for increasing uniformity of the air bearing surface (ABS) of a slider. Still more particularly, the present invention relates to a method and apparatus for improving the capacity of an ion beam grid to uniformly etch an ABS specimen.

2. Description of the Prior Art

[0003]Generally, a data access and storage system consists of one or more storage devices that store data on magnetic or optical storage media. For example, a magnetic storage device is known as a direct access storage device (DASD) or a hard disk drive (HDD) and includes one or more disks and a disk controller to manage local operations concerning the disks. Disks are rigid platters, typically made of aluminum alloy or a mixture of glass and ceramic, covered with a magnetic coating. Typically, two or three disks are stacked

vertically on a common spindle that is turned by a disk drive motor at several thousand revolutions per minute (rpm).

[0004]The only other moving part within a typical HDD is the head stack assembly. Within most HDDs, one magnetic read/write head or slider is associated with each side of each platter and flies just above or below the platter=s surface. Each read/write head is mounted on a suspension to form a head gimbal assembly (HGA). The HGA is then attached to a semi-rigid arm apparatus that supports the entire head flying unit. Several semi-rigid arms may be combined to form a single armature unit.

[0005]Each read/write head scans the surface of a disk during a Aread@ or Awrite@ operation. The head and arm assembly is moved utilizing an actuator that is often a voice coil motor (VCM). The stator of a VCM is mounted to a base plate or casting on which the spindle is also mounted. The base casting is in turn mounted to a frame via a compliant suspension. When current is fed to the motor, the VCM develops force or torque that is substantially proportional to the applied current. The arm acceleration is therefore substantially proportional to the magnitude of the current. As the read/write head approaches a desired track, a reverse polarity signal is applied to the actuator, causing the signal to act as a brake, and ideally causing the read/write head to stop directly over the desired track.

[0006]In a typical magnetic head slider fabrication process, ion milling has been one of the more popular techniques to form an air bearing surface (ABS) on the slider. The ABS allows the slider to be flown very close to a disk in order to retrieve or rewrite information in the disk. With the increasing demand on storage density, fly height (i.e., the altitude that the slider flies at relative to the disk) has become the most critical parameter to differentiate drive performance. In order to have sufficient control of the fly height, the etch depth

uniformity of the ABS must be improved beyond the present tooling capacity.

[0007]As graphically illustrated in **Figure 1**, the etch depth uniformity of a specimen **11** is typically controlled by an ion beam etching device **13** via a grid **15** formed from a durable material such as molybdenum. Specimen **11** is rotated as shown on a table **17** about its center, or grid **15** is rotated relative to specimen **11**. Grid 15 is mounted to a stationary ion beam gun **19** directly above specimen **11**. Grid **15** has a large number of symmetrically spaced-apart holes **21** and voids **22** that are free of holes **21** (see **Figure 2**). The center **23** of grid **15** is concentric with the center of specimen **11**. As specimen **11** is rotated, ion gun **19** emits a large axially-directed beam **25** onto the upper surface of grid **15** such that a grid filters beam **25** and small ion beamlets **27** permeate each of holes **21** to etch specimen **11**. Although it is possible to redesign the grid using complicated ion optics theories in order to enhance the etch depth uniformity of the ABS, this solution is difficult and relatively expensive. Thus, an improved apparatus and method for increasing the uniformity of ABS etching depth is needed.

SUMMARY OF THE INVENTION

[0008] A shaper for an ion beam gun is a thin, flat plate having a generally elongated, non-symmetrical profile with notches and tabs. The shaper is mounted flat to the surface of an ion beam grid having an array of holes. The shaper is oriented radially on the grid from its center to a perimeter of the grid and covers some of the holes in the grid. The grid is mounted to an ion beam gun above a specimen that is rotated beneath the ion beam gun. The large ion beam is filtered into smaller ion beamlets by the grid. The ion beamlets permeate the holes in the grid that are not covered by the shaper. The ion beamlets reach the specimen to etch it more uniformly than a grid that does not have a shaper. This phenomena is due to blockage of the higher ion beam density along the radial direction. The ion beamlets that ultimately arrive at the specimen are themselves more uniform and can produce the more uniform pattern on the specimen. The shaper may be further optimized for a particular grid via a trial-and-error process to even further refine the uniformity of etching depth.

[0009] The foregoing and other objects and advantages of the present invention will be apparent to those skilled in the art, in view of the following detailed description of the preferred embodiment of the present invention, taken in conjunction with the appended claims and the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[00010]So that the manner in which the features, advantages and objects of the invention, as well as others which will become apparent, are attained and can be understood in more detail, more particular description of the invention briefly summarized above may be had by reference to the embodiment thereof which is illustrated in the appended drawings, which drawings form a part of this specification. It is to be noted, however, that the drawings illustrate only a preferred embodiment of the invention and is therefore not to be considered limiting of its scope as the invention may admit to other equally effective embodiments.

[00011]Figure 1 is a schematic side view of a prior art ion beam etching device in operation;

[00012]Figure 2 is a plan view of a prior art ion beam grid used by the device of **Figure 1**;

[00013]Figure 3 is a plan view of a first embodiment of an ion beam grid shaper constructed in accordance with the invention;

[00014]Figure 4 is a plan view of a second embodiment of an ion beam grid shaper constructed in accordance with the invention;

[00015]Figure 5 is a plan view of a third embodiment of an ion beam grid shaper constructed in accordance with the invention and shown mounted to a grid;

[00016]Figure 6 is a plot of etch depth uniformity on a specimen etched with a prior art grid;

[00017]Figure 7 is a plot of etch depth uniformity on a specimen etched with a grid equipped with the shaper of **Figure 3**; and

[00018]Figure 8 is a plot of etch depth uniformity on a specimen etched with a grid equipped with the shaper of **Figure 4**.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[00019]Referring to **Figure 3**, a first embodiment of a shaper **31** for an ion beam gun, such as the one illustrated and described in **Figure 1**, is shown. Shaper **31** is essentially a thin, flat sheet or plate formed from a durable material such as molybdenum. In the preferred embodiment, shaper **31** is formed from the same material as the ion beam grid that the ion beam grid will be attached to. Shaper **31** is also uniquely shaped for the particular application of its design and, thus, is precisely customized via an empirical or trial-and-error process. Shaper **31** has an elongated neck portion **33** with a mounting hole **34**, a generally rectangular front portion **35**, and a bulkier mid-section **37** that generally tapers to a small tail portion **39**. Mid-section **37** typically has a unique, non-symmetrical profile including notches **41** and tabs **43** that increase ion beam etching uniformity.

[00020] A second illustrative embodiment of shaper **31** is depicted in **Figure 4** as shaper **45**. Shaper **45** is substantially similar to shaper **31** including neck, front, middle, and tail portions, but has a slightly different geometry as shown.

[00021] Although Ashapers@ are widely used in ion beam sputter deposition or direct ion beam deposition to achieve uniform deposition, those prior art devices differ significantly from the present invention that is mounted directly to the ion beam gun itself. The shaper used in deposition is typically in front of the substrate being deposited. By manipulating the shaper position relative to the incoming flux of depositing material, the thickness uniformity of the resultant film may be improved. This type of shaper is used in DC, RF sputtering, as well as ion beam sputter deposition systems. However, it is not suitable for etching uniformity because the shaper would be etched away and become a source of contamination. The present invention places the shaper inside the ion gun, such that no such concern exists.

[00022]In operation, a third illustrative embodiment of a shaper **51** is shown mounted directly to an ion beam grid **53** having a large plurality of holes **55** and voids **57** that are free of holes **55**. The surface area of shaper **51** is relatively small compared to the overall surface area of grid **53** and typically covers less than 5% of grid, preferably 1 to 5% thereof. Shaper **51** may be secured to either the upper or lower surface of grid **53** via a number of different fastening methods including screws. The hole **59** in the neck portion of shaper **51** is aligned and fastened to the center of grid **53**. The remainder of the body of shaper **51** covers a radial swath of grid **53** and extends from the center of grid **53** to a perimeter thereof and is secured with an appropriate number of fastening mechanisms. In this version, the mid-section and tail portion of shaper **51** are used to cover one of the voids **57** in grid **53**. With shaper **51** rigidly attached to grid **53**, a significant number of the holes **55** in grid **53** (but less than 5%) are covered or sealed. The geometry of shaper **51** is determined by the etch depth profile along the radial direction of grid **53**.

[00023]Grid **53** is then mounted to the lower end of a stationary ion beam gun (see **Figure 1**) which is located directly over a rotatable table supporting an ABS specimen. Grid **53** may be parallel to the specimen or skewed relative thereto. As the table rotates the specimen concentrically beneath the gun, ion beamlets permeate the holes **55** in grid **53** that are not covered by shaper **51**. The ion beamlets that are allowed to reach the specimen etch a more uniform ABS on the specimen than a grid **53** that is not configured with a shaper **51**. This phenomena is due to the blockage of the higher ion beam density along the radial direction. The ion beamlets that ultimately arrive at the specimen are themselves more uniform and, thus, produce an even more uniform pattern on the specimen. Since shaper **51** reduces the ion beam density emanating from grid **53**, there is a reduction in the total beam intensity and a concomitant reduction in the etching rate (about 5%) at a given beam

power. However, a much better uniformity is achieved. Shaper **51** may be further optimized for grid **53** via an empirical or trial-and-error process to even further refine the uniformity of etching depth.

[00024] Referring now to **Figure 6**, an illustrative plot **61** of the surface uniformity of the specimen **11** etched by grid **21** of **Figure 2** is shown. The vertical axis of **Figure 6** depicts the vertical dimension or depth (in angstroms) of the etching in the surface of specimen **11**, and the horizontal axis depicts the radial distance (in millimeters) from the center of specimen **11**. In other words, plot **61** is essentially an enhanced cross-sectional view of specimen **11** that schematically illustrates the flatness and uniformity of its ABS. The average etch depth of specimen **11** is 5,215 angstroms with a standard deviation of 214 angstroms or 4.1%.

[00025] **Figure 7** is a plot **63** of the surface uniformity of a specimen etched by a grid equipped with shaper **31** of **Figure 3**. The vertical and horizontal axes of **Figure 7** are the same as for **Figure** 6. The average etch depth of the specimen etched via shaper **31** is 4,918 angstroms with a standard deviation of 108 angstroms or 2.2%. This is a significant improvement over the previous grid **21** having no shaper. Shaper **31** reduced the standard deviation by almost half compared to the prior art apparatus and method. Although shaper **31** was a significant improvement, it overcompensated the middle portion of the ion beam by blocking too many beamlets in this area. Thus, shaper **45** of **Figure 4** was designed to further refine shaper **31**.

[00026] **Figure 8** is a plot **65** of the surface uniformity of a specimen etched by a grid equipped with shaper **45**. The average etch depth of the specimen etched via shaper **45** is 4,966 angstroms with a standard deviation of 85 angstroms or 1.7%. This is an even greater improvement over prior art grid **21** having no shaper, and over a grip equipped with

shaper **31**. Shaper **45** offers an improvement of about 58% over grid **21**, and about 23% over shaper **31**. As stated previously, a shaper may be further optimized for a particular grid via trial-and-error to even further refine the uniformity of etching depth.

[00027] The invention has several advantages. The apparatus and method disclosed above improves etch depth uniformity with a shaper that can be optimized without redesigning the ion beam grid using complicated ion optics theories. The shaper of the present invention blocks the higher density beam portions to achieve a more uniform ion beam and, thus, a more uniform etch. The shaper of the present invention improves the etching depth uniformity of an ion beam gun by over 50% in some applications.

[00028] While the invention has been shown or described in only some of its forms, it should be apparent to those skilled in the art that it is not so limited, but is susceptible to various changes without departing from the scope of the invention.